machines. About one-half the creosote is required for a paper barrier as for a line barrier, but savings in the cost of creosote are more than compensated for in the cost of the paper and barrier construction.

Dinitro-*o*-cresol dust makes an effective barrier. It is prepared by mixing thoroughly 4 pounds of dinitro-*o*-cresol and 96 pounds of pyrophyllite dust. The mixed dust is applied in a strip 2 inches wide along the field that is being invaded. This barrier is easily disturbed by winds and the feet of animals. Its advantages are the saving of time in applying it and the fact that it kills the bugs that crawl through the dust in the barrier line. From 1 to 2 pounds of mixed dust is required to erect and maintain 1 rod of dinitro-*o*-cresol dust barrier.

Regardless of the kind of material used to construct a barrier, additional material must be applied to maintain an effective barrier for 10 days or 2 weeks or until the invasion ceases.

Direct control of chinch bugs by the application of sprays or dusts to infested crops may be practical now in some instances, using the newer insecticides. Insecticides have not been tested extensively against field-wide infestations, because infestations of chinch bugs have been nearly noneconomic since the chlorinated hydrocarbons became available.

Populations of chinch bugs fluctuate from year to year, as indicated by the fact that nearly 9,000,000 rods of barrier were constructed in 1934 and only 94,000 rods in the following year. Another year of high populations was 1940, when 2,221,000 rods of barrier were used to protect crops. After a survey in 1944, it was estimated that 7.5 million rods of barrier would be needed in 1945. Only 273,000 rods of barrier were constructed, however, because weather unfavorable to chinch bugs abruptly reduced their numbers.

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The European Corn Borer

Wm. G. Bradley

A research worker of the Massachusetts Agricultural Experiment Station in 1917 discovered several pinkish-brown worms on sweet corn in market gardens near Boston. Specialists examined the larvae and found them to be a species that was a pest of corn in Europe. A bit of sleuthing disclosed that they had sneaked into this country a few years earlier in broomcorn imported probably from Italy or Hungary for use in broom factories in Medford, Mass.

Sometimes quickly, sometimes more slowly, the insect, the European corn borer, spread outward from its original point of infestation. By 1952 it had been found in 37 States east of the Rocky Mountains, in which are most of our main corn-growing sections. The losses it caused in field corn were estimated at 314 million bushels in 1949.

From studies of the biology and habits of the insect we learned that two strains of the borer now exist in the United States. The single-generation, or univoltine, strain passes through one life cycle a year. The multiple-generation strain has two or more complete cycles every 12 months, depending on environment.

The multiple-generation strain flourishes in nearly all of the infested area, although its proportion to the single-generation strain varies in different localities, reaching its maximum in the southern sections and diminishing toward the north.

Observation of hundreds of species of plants in the field and tests in experimental plots on plants from many parts of the country showed that the borer can live on more than 200 different kinds of wild and cultivated plants. Corn, however, is infested and injured by the larvae, or borers, to a greater extent than any other crop. The borer injures field corn (both dent and flint), sweet corn, popcorn, and corn planted for fodder or silage. In the western part of the Corn Belt, corn is practically the only cultivated plant that is infested or injured to any extent. Broomcorn, soybean, millet, oats, potato, pepper, sorghum, and some large-stemmed flowering plants may be attacked when they are grown near corn or in years when corn matures late.

In the East, where the multiple-generation strain predominates, it commonly infests many other plants, including vegetables, field crops, flowers, and weeds. Many of them serve as shelter for the borers, rather than as food, and are infested sometimes by the borers which "overflow" from corn and other favorite host plants growing nearby.

THE EUROPEAN CORN BORER is essentially a boring insect and its greatest injury results from the tunneling and feeding of the larvae within the stalk, ears, tassel, midrib of the leaf, brace roots—practically all parts of the corn plant except the fibrous roots. The larvae also feed to some extent upon the leaf blades in the whorl, tassel buds, husks and silks of the ear, and behind the leaf sheaths.

The character of the injury depends on the stage of development of the corn plant when it is attacked. Soon after hatching, the borers begin migrating to various parts of the same plant or to other plants nearby. The developing whorl is a favorite feeding place for newly hatched larvae. If the attacked plant is just developing a tassel, some of the small borers enter the tassel buds and feed within; others eat the surface of the tassel buds and protect themselves with a slight silken web. If the infestation occurs at the time of pollen shedding, accumulations of the pollen at the ligules supply favorable material on which the larvae feed. Later they tunnel within the tassel stem and its branches, often causing it to break over. These broken tassels, with bunches of sawdustlike borings at the breaks, are the outstanding signs of infestation in fields of growing corn, although many infested plants may not show this particular injury. The borers may continue tunneling downward into the main stalk, or they may leave the upper part of the plant and enter it or neighboring plants at points lower down. Some of the newly hatched borers, instead of feeding upon or within the tassel buds and tassel stalks, enter the stalk directly at some lower point.

The borers usually enter between the leaf sheath and stalk or between the stalk and the base of the partly developed ear if the plant has advanced to that stage of development. As they gradually increase in size, they make larger tunnels and work upward or downward. Small holes in the stalks, with bunches of sawdustlike borings at or below them, indicate the section in which the borer is at work.

At any stage of their development the borers may enter the ear directly at its tip, base, or side; or they may enter it indirectly through the short stem, or shank, by which the ear is attached to the stalk, in which case the shank is often so weakened by the injury that it breaks over. Frequently the ear is entered at its tip by small borers, which feed first upon the silks or the tender portion of the husk and then work their way down into the cob and grain.

The injury to stalks and ears may be increased still further by disease organisms, which often follow the work of the borers and gain entrance through lesions made by borers.

THE EUROPEAN CORN BORER passes the winter as a fully grown borer, or worm, inside its tunnel in the stalk, stubble, or ear of corn, or in some weed or other plant. The presence of the borers may be detected by small holes on the surface of the infested plants which are usually plugged with castings. When you split open the stalks or stubs, you usually find the borers inside. They are then nearly an inch long and one-eighth inch thick. The head is dark brown or black. The upper surface of the body ranges in color from light brown to dark brown, or it may be pink. Each division of the body bears a row of small, dark-brown spots; several narrow dark-brown or pink lines extend lengthwise of the body. The under side of the body is flesh-colored and is without markings.

As soon as warm weather begins, in April or May, the borer may leave its winter shelter and bore into more suitable places to pass the resting stage.

In May or early June it cuts a small circular opening from its tunnel to the surface of the plant to provide an exit for the future moth. It then closes the hole with a thin webbing of silk and retreats into its tunnel to a point near the last feeding or shelter place, where it usually spins a thin cocoon. Inside the cocoon the borer changes into the resting stage, or pupa, which is shuttle-shaped, light brown to dark brown, and one-half to five-eighths inch long. After 10 to 14 days the skin of the pupa case splits, and the moth, or adult, comes forth and (under average weather conditions) is present in the fields from June to September.

The females begin to lay their eggs soon after they emerge. The moths remain quiet during the day, hiding in patches of weeds and grass or underneath the leaves of other plants. Evenings and sometimes through the night when the weather is good, they fly from plant to plant and lay their eggs in flat, irregular masses. A female lays up to 1,900 eggs; the average is about 400. The moths live 10 to 24 days. An egg mass usually contains 15 to 20 eggs; as many as 162 have been found in a single mass, although eggs deposited singly may be observed. The masses are laid mainly on the under surface of the corn leaves, although they are sometimes laid on the upper surface, on the stalk, or on the husk. Each egg is about half the size of an ordinary pinhead; in the masses the eggs overlap like fish scales. The egg is nearly flat and is white when first laid, but later changes to pale yellow and becomes darker just before the young borer comes out.

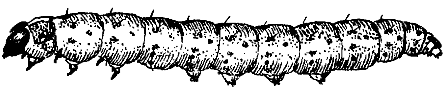
The eggs hatch in 4 to 9 days, depending on the temperature. The newly hatched borer, about one-sixteenth inch long, has a black head and a pale yellow body, which bears several rows of small black or brown spots. During its growth the borer molts or changes its skin five or six times, gradually increasing in size with each change until it becomes full-grown.

Borers of the single-generation strain become full-grown in August if weather conditions are normal. They continue to feed, or bore, however, at intervals until cold weather stops their activities in October or November. They remain in a dormant condition throughout the winter within their tunnels in the cornstalks, stubble, cobs, or other plant remnants.

Soon after they discovered the borer in the United States, investigators tried to establish biological controls like the ones that exist in its native haunts.

During the investigations, which started in 1919 and have continued since, more than 23 million borer larvae and pupae from Europe and 3 million from the Orient were brought to the United States. From them the natural enemies were reared. Other parasites were collected and forwarded to this country in the cocoon or pupal stages. Of the 24 species included in the importations, 21 were numerous enough to permit colonization over the borer-infested area in this country. The number of parasites available for colonization obtained from host larvae and pupae or parasite cocoons and pupae shipped from Europe or the Orient exceeded 2.5 million; it was increased by breeding in laboratories and by domestic field collections. About 8.5 million adults from all sources were released in fields.

Entomologists set loose adult parasites at selected localities throughout the infested area where the borer was sufficiently abundant to support a parasite population. The scientists conducted surveys in the vicinity of these localities to determine which species



European corn borer.

became established and to get information on their biology as an aid in increasing their distribution within previously colonized areas and in colonizing areas newly infested by the natural spread of the borer. The species known to have become established in the United States and the number of adults of each that were released are: *Lydella stabulans grisescens* (838,966); *Horogenes punctorius* (198,145); *Macrocentrus gifuenis* (2,610,654); *Sympiesis viridula* (394,382); *Chelonus annulipes* (401,983); and *Phaeogenes nigridens* (53,234).

To determine the effects of the parasites, scientists developed special sampling designs and techniques. Among them were polar coordinate designs suitable for studying extent of establishment, rates and direction of dispersion, and other pertinent points. These designs consisted of sections to aid in randomizing samples in concentric rings about a central circle surrounding the release point. The number of sections in each ring and the width of the ring were varied to suit the objectives sought.

The studies showed that the parasites have spread at varying rates from the many release points. From the older colonies in the East where they have been present 20 years or more, some species have been found at distant points. In the North Central States, where colonization is more recent, some establishment and dispersion of a number of the species have occurred. It is hard to evaluate accurately the economic benefit derived from the parasites, but in many sections parasitization of more than 50 percent of the borers has been observed; average parasitization over considerable areas is high enough to indicate that many borers are being killed by the parasites.

Twenty-nine species of insects indigenous to the infested area parasitize the borer. None has been numerous enough to have a great effect on the borers. Scientists have tried to supplement the natural occurrence of *Trichogramma minutum,* a parasite that occasionally destroys a high percentage of the later portion of the second-generation eggs, by rearing a stock supply of parasites in the laboratory and releasing them when first- or second-generation eggs were present. Neither permanent nor appreciable temporary benefit resulted from the efforts.

Predators exert some influence on the borers.

Birds, particularly the downy woodpecker (*Dryobates pubescens medianus*) and the red-winged blackbird (*Agelaius phoeniceus phoeniceus*), and insect predators, particularly the lady beetles *Ceratomegilla fuscilabris* and *Hippodamia convergens,* have been frequently observed removing large numbers of borer larvae and egg masses from corn plants. No predators have been imported for testing against the corn borer.

The only disease organism that has been observed to kill the corn borer in the field in the United States is *Beauveria bassiana* and then only under circumstances directly traceable to infection originating in the laboratory. *B. bassiana* is an insectivorous organism that probably was brought into the United States on imported larvae. Field recoveries of this disease have been made immediately following its dissemination, but evidently no lasting effect has resulted from efforts to establish it as a natural control.

THE DISPOSAL of host plants in such a way as to destroy the borers infesting them is a logical and effective way to combat the borer. We have conducted a great deal of research to determine the best ways to do that. By the use of traps, for catching surviving borers, consisting of a rectangle of boards set on edge in the test ground and lined on the inside with strips of corrugated paper, the most efficient equipment was developed and information on the number of borers killed as a result of being buried at various depths in many types of soil was obtained. Because of the ability of the borer to reproduce at a very high rate and because of the mortality caused by many natural factors it is doubtful if disposal of host plants will prove highly beneficial unless a thorough community-wide effort is made. Because most of the mechanical methods of control are actually good farm practices, however, it is wise to follow them.

Feeding infested plants to livestock is one way to fight the corn borer. Their food value is not noticeably reduced unless they are severely infested. Infested corn plants can be fed as silage, direct from the field, or as finely shredded or cut fodder. Properly done, any of these methods destroys nearly all the borers in the plants.

Any infested corn that is put in the silo should be cut close to the ground. Borers that escape the silage cutter are destroyed in the silo.

Infested cornstalks must be cut into pieces not longer than a half inch so that nearly all the borers may be killed. This precaution is particularly important if the silage is not placed directly in the silo or is not fed soon after it is cut.

If cutting and shocking in the field is done, the corn should be cut low and early. Low cutting also helps in doing a clean job of plowing later and makes other clean-up methods easier.

In general, the proportion of borers living in the stalk below any given height increases as the season advances.

If infested cornstalks are fed directly without previous cutting or shredding, the uneaten parts should be collected and destroyed unless they are trampled completely by livestock and thoroughly mixed with the manure of the feed lot.

Shredding or cutting corn fodder into fine pieces, as is ordinarily done by husking and shredding machines, kills 95 to 98 percent of the borers and makes the fodder more acceptable to livestock. Most of the borers that escape death in the machine perish during the general practice of storing the shredded material, feeding it to livestock, and using the residue as bedding, which is finally trampled into the manure.

Stalk cutters, which break up the stalks in the field, probably do not kill on an average more than 60 percent of the borers present, but they promote more rapid rotting of the stalks and make clean plowing easier.

Effective plowing to control borers depends on turning under the corn remnants and other trash so completely that none of it remains on the soil surface. The material plowed under should not be dragged to the surface by later cultivation before the moths emerge, and the ground should be cultivated or pulverized to close all large cracks and crevices.

Plowing infested material under does not itself kill the borers. Most of the borers crawl up to the surface sooner or later. If the plowing has been clean, however, most of the larvae coming to the surface die because they are exposed to natural enemies like birds, ants, ground beetles, and insect parasites and predators. But if the plowing is not done clean, the borers, when they reach the surface, bore into any fragments of a corn plant or weed that may be left there and with that protection they can complete their development to the moth stage.

The depth of plowing for corn borer control is not important if all infested material is covered completely to such a depth that it will not again be brought to the soil surface by later cultivation or weathering and thus become a shelter for the borers that crawl on the surface. To insure proper coverage, however, and to reduce the possibility of the plowed-under material being again dragged to the surface, plowing to a depth of 6 inches or more should be done if soil conditions permit.

An effective plow attachment to aid in turning under trash consists of three No. 9 gage wires. The wires, about 12 feet long, are attached to the framework of the plow, and the outer ends are left loose. The loose ends are caught by the furrow slice as it is turned over. Thus the wires are held tightly to the top of the furrow slice by the weight of the soil on the buried ends of the wires and so turn all trash to the bottom of the furrow.

Disking cornstalks or high stubble in preparation for seeding to small grain or other crops is objectionable from the the standpoint of corn borer control, except when it is followed by clean plowing. Disking allows a very high percentage of borers to survive and the shade given later by the growing grain protects the borers in the trash left on the surface.

Rolling, soil packing, disking, or other similar types of cultivation are of practically no value in combatting the borers.

INSECTICIDES are effective for protecting corn from damage by the borer.

Research has been directed toward finding more efficient and economical insecticides. In recent years nozzles have been developed and tested to deliver sprays with droplets of satisfactory size and under efficient pressures to be carried from the nozzles to the whorls, leaf axils, and other parts of the plants where the borers feed. Chemists have produced new and highly toxic insecticides and formulations have been modified to permit practical low application rates with freedom from nozzle clogging and with the ability to penetrate into the concealed plant parts where the larvae feed and to remain on the plants for several days. In the search for new insecticide material research workers have attempted to keep the toxicity to plants and warm-blooded animals as low as possible.

EACH YEAR several hundred compounds have been developed by the division of insecticide investigations and tested to determine their effectiveness in controlling the borer. Many of these materials are powders ground from parts of plants from foreign lands. In this work extremely accurate tests are conducted in the laboratory to find the most promising insecticides. These are next given further tests in small plots in the field and those found effective are then given large-scale field tests.

Because the borer feeds in concealed places and because of the growth characteristics of the corn plant, application equipment differing greatly from that used on row-crop pests had to be designed.

State agricultural agencies in most of the infested States have established services whereby the progress of corn and borer development is followed, and they can furnish reliable advice on timing of application, as well as on other problems relating to corn borer control.

Corn should be planted at the time which normally will allow it to produce its maximum yield in the locality in which it is grown as recommended by the State agricultural agencies. Avoiding early planting protects against heavy infestation by first-generation borers as well as the danger of poor germination and possibly frost damage in spring. Avoiding late planting protects against damage from second-generation borers and from the possibility of early frost damage and soft corn in the fall.

No strain of corn has shown complete immunity from corn borers. Some strains have inherent characteristics that enable them to resist or tolerate the borers better than others. The number of borers per plant at harvest, as compared with the number of corn borer eggs originally on the plants, is much smaller in some strains of corn than in others. Also some strains of corn will stand up better than others under an attack by a given number of borers. Plant breeders are taking advantage of the information obtained relative to the resistance of commonly used corn inbreds and those recently developed on the basis of borer resistance to provide growers with hybrids which can be expected to produce a satisfactory yield in the borer-infested localities.

Research to determine these points involved the study of thousands of lines of corn obtained from all parts of the world. Observations were made on such widely divergent material as open-pollinated varieties from Mexico and South America, areas in which corn was thought to have had its origin, open-pollinated corn grown for years under corn borer conditions in Europe, lines developed by breeders to provide resistance to other insects, germ plasm brought down from corn grown originally by the Indians in the United States, hundreds of lines developed by breeders searching for improved agronomic characters and many others.

In order to determine accurately the relative differences in resistance between the various lines of corn it was necessary that each should be infested with borers as nearly uniform as possible. To obtain this objective and to insure that tests could be made even in years of low natural borer infestation, many thousands of corn borer eggs are produced each year under laboratory conditions and placed on the test plants by hand. To promote the success and efficiency of this method many pieces of equipment and specific techniques were developed. Moths reared in large emergence cages are induced to lay eggs on wax paper. Egg-cutting machines capable of turning out 10,000 masses on wax-paper disks per day were utilized. Storage conditions for ovipositing moths and eggs were studied and improved in order to increase the efficiency of this research.

No one of the methods discussed gives all the control needed, but crop losses from corn borers can be cut by their use. The amount of benefit obtained will depend on favorable or unfavorable weather, how many of the control methods are used, and how well these are carried out.

While the grower has at hand means of saving his corn from serious injury, it should be the objective of research to reduce the threat so that no additional control methods would be necessary, other than those which would be followed in sound farm practice in the absence of the borer, or to reduce the cost in labor, money, and equipment of recommended control measures enough to promote their universal adoption.

To further the first of these objectives continued search should be made in all the corn-growing areas of the world to find and utilize germ plasm of high resistance to the borer. Incorporation of this material into agronomically desirable hybrids for use within the infested area would bring about substantial savings without seasonal outlays of funds for direct control measures.

Although the outlook for biological control seems encouraging, continued search should be made in those parts of the world where the borer is present but in which no investigations on parasites have been conducted. A more thorough study of predators and their utilization should be made and the role of such beneficial insects in the countries in which the borer is indigenous should be studied. An efficient combination of parasites, predators, and disease organisms would aid materially in reducing borer damage.

Research with respect to the second objective would involve the development of more efficient insecticides, application equipment, and application methods. More infallible and practical means of determining whether or not to treat and when to treat would be a distinct advance. Some studies have been made on systemic poisons. A number of systemic poisons have been tested both in the laboratory and in the field by mixing the materials in various dosages with the soil in which corn is grown. High mortality of larvae feeding on corn so treated has been produced. This work should be continued as it points to the possibility of a control measure which can be utilized with little additional cost to the farmer.

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Insects That Attack Tobacco

D. J. Caffrey

Tobacco is subject to damage by several species of insects from the time the seedlings develop in the plant bed until the crop is harvested, during the time it is in storage, and after the manufactured products have been prepared and offered for sale.

The insects that attack the seedling tobacco or the growing crop include hornworms, flea beetles, aphids, cutworms, green June beetle larvae, tobacco budworms, and wireworms.

Others, less widely distributed, are webworms, thrips, grasshoppers, mole crickets, vegetable weevils, midge larvae, slugs, and suckflies.

The cigarette beetle commonly infests practically all types of tobacco in storage. Stored tobacco of the flue-cured domestic and imported Turkish types used in making cigarettes is also menaced by the tobacco moth. All kinds of tobacco products—cigars, cigarettes, smoking and chewing tobacco, and snuff—may be mutilated and contaminated by the cigarette beetle.

Despite many years of research and the development of fairly good remedies, insects continue to cause impressive losses—an estimated loss of 100 million dollars annually to the growing crop and 5 million to 10 million dollars to the stored and manufactured product in recent years. One appreciates the losses when he remembers that tobacco has been a commercial crop in the United States since 1612, it had a farm value of more than 1 billion dollars in 1950, and in that year was grown on 1,593,900 acres through the Southern, Central, and Eastern States.

In plant beds the tobacco seedlings are attacked commonly by flea beetles,